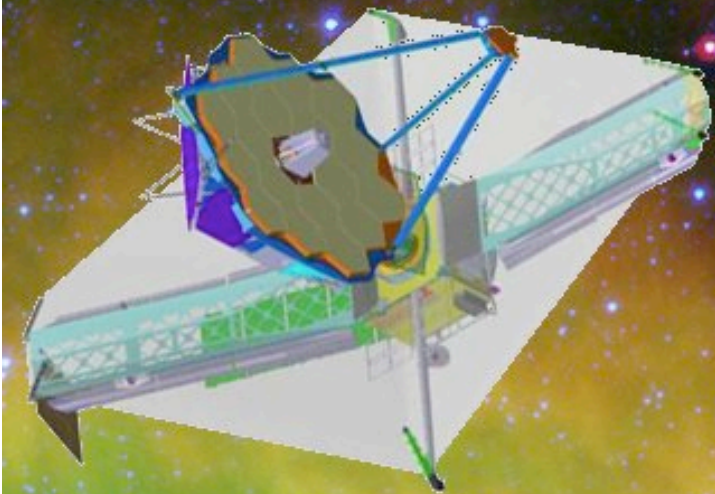




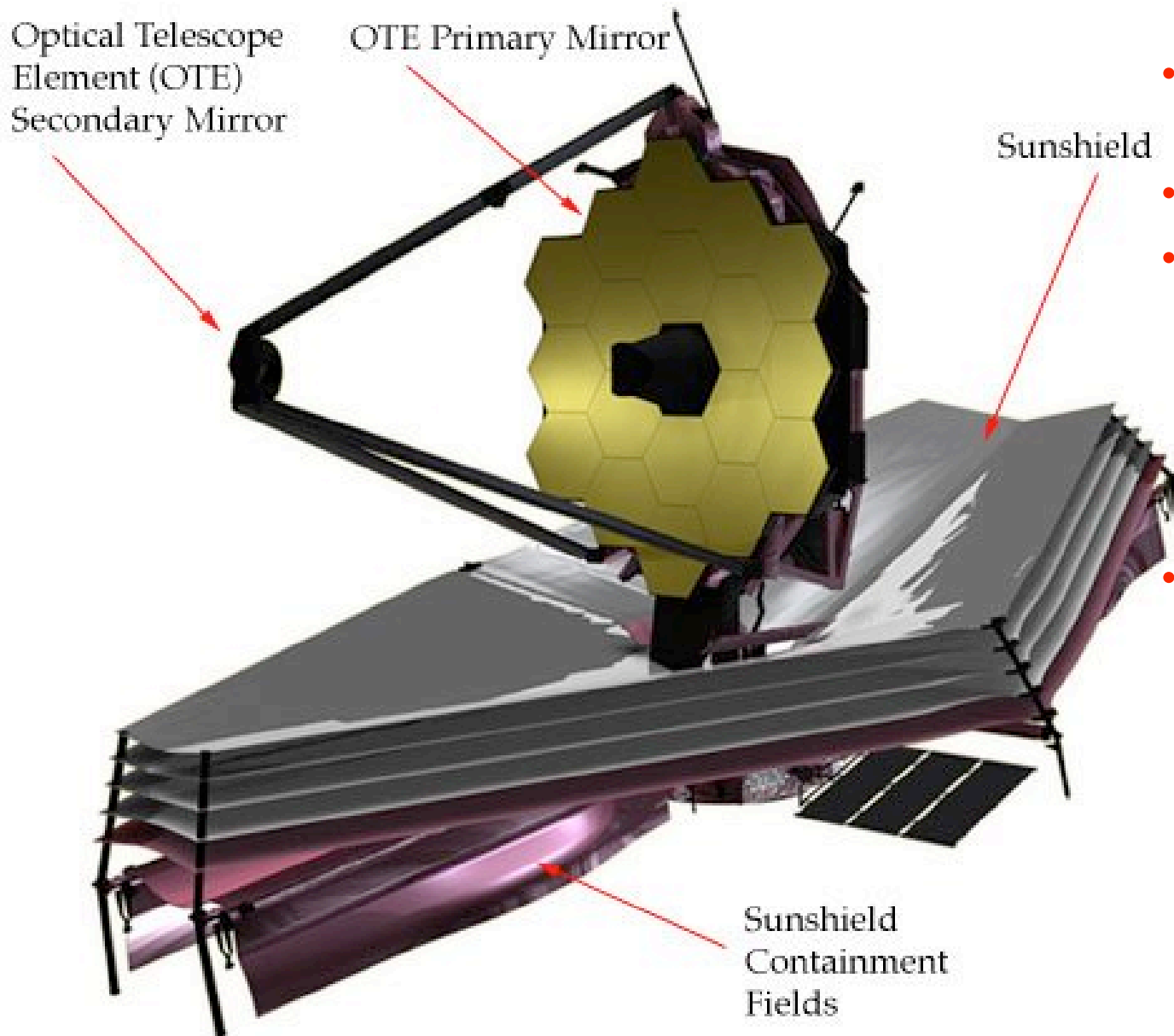
James Webb Space Telescope (JWST) and Star Formation

Zermatt ISM meeting
September 24, 2010
Tom Greene (NASA Ames)
& many other JWST scientists



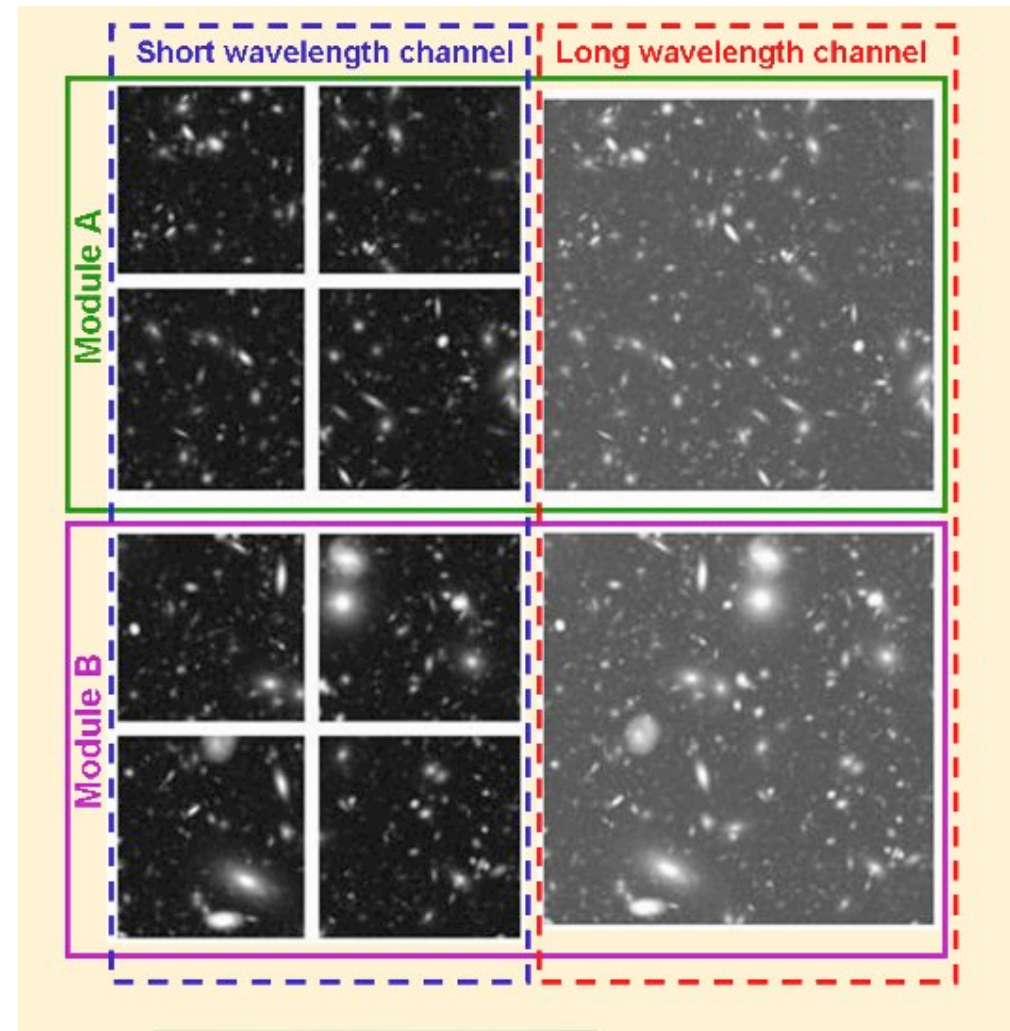
Spitzer Serpens A image courtesy of NASA/JPL-Caltech/L. Cieza (UT)

JWST in a nutshell



- 6.5-m primary mirror; 18 segments
- $\lambda < 1 - 28 \mu\text{m}$
- Instruments:
 - NIRCam
 - NIRSpec
 - MIRI (cam + spec)
 - FGS w/TF
- ≥ 2014 launch
 - Ariane V to L2
 - 5 yr req life
 - 10 yr goal
 - No cryogenics

- Images over $0.7 - 5 \mu\text{m}$
Nyquist sampled at $2 \text{ \& } 4 \mu\text{m}$
 - Broad, medium, and narrow bands
 - $R \sim 1700$ slitless spectra $3 - 5 \mu\text{m}$ (series filter)
 - Coronagraphic imaging
- 2 identical modules, each with short and long wavelength dichroics: $2 \times 2' \times 2'$ FOV
- M. Rieke (U Arizona) is PI
- Filters and other information:
<http://ircamera.as.arizona.edu/nircam/>





FGS: Fine Guidance Sensor (CSA)



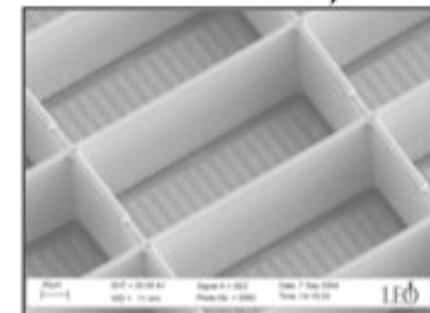
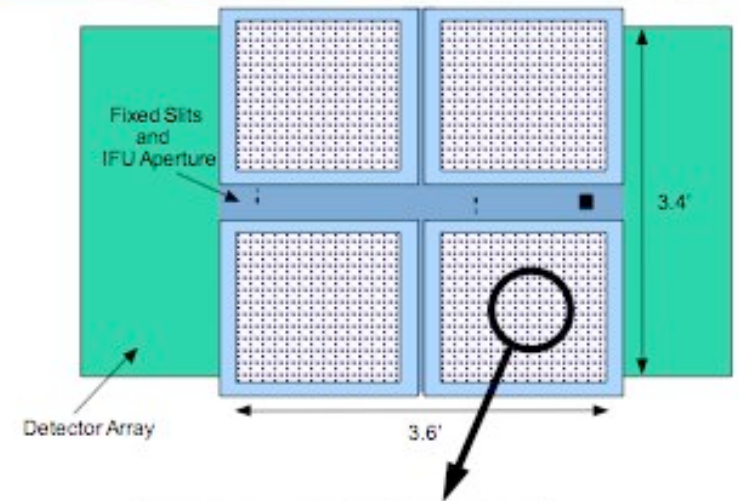
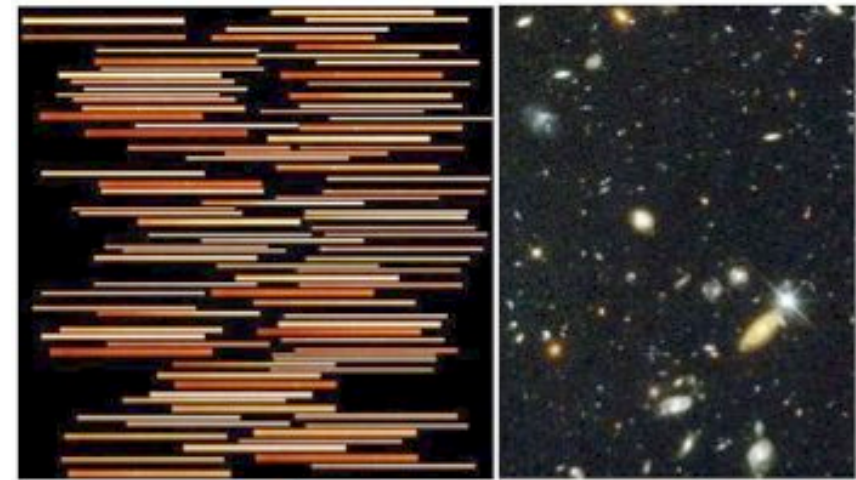
- 2 NIRCams-sized (2.3' x 2.3' adjacent FOVs)
 - $\lambda = 2\mu\text{m}$ critical sampling
- $\lambda = 0.8 - 4.8 \mu\text{m}$ wide band guider imaging
- R=100 imaging with tunable filter (TFI) for science
 - $\lambda = 1.5 - 2.6 \mu\text{m}$ and $3.1 - 5 \mu\text{m}$ operation
- Non-redundant mask for moderate contrast, high spatial resolution science imaging
- J. Hutchings (FGS) and R. Doyon (TFI) are PIs



NIRSpec (ESA): 1 – 5 μm spectra

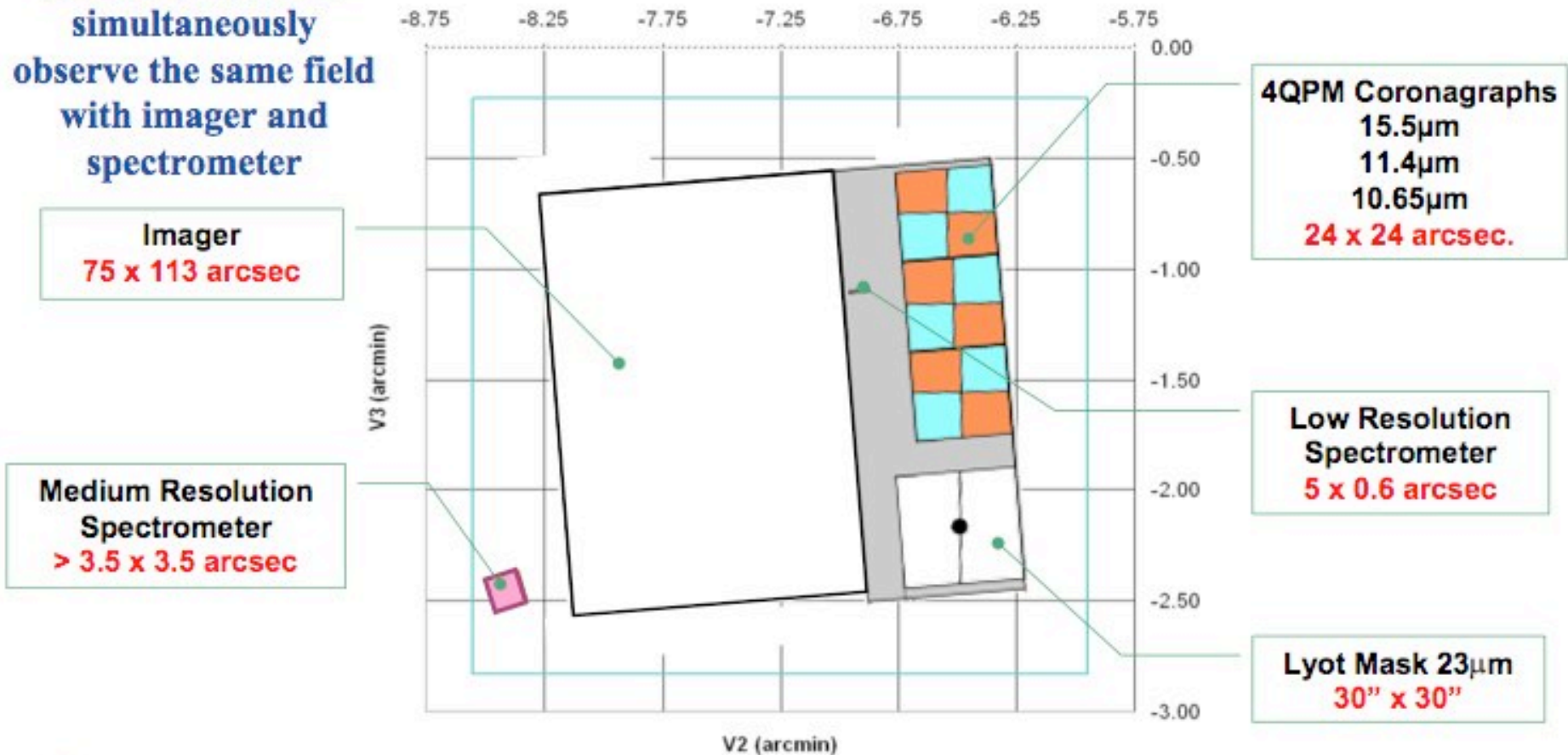


- Multi-object spectrograph
 - 3.4' x 3.4' FOV
 - Mosaic of microshutter arrays (250,000 shutters, each 200 x 460 mas)
- Also has fixed slits and IFU
- R=100 (1 setting) and R=2700 (3 settings) spectroscopy with coarse (100 mas) spatial sampling for single or multiple objects
- R~100 prism covers 0.7 – 5 μm
- P. Jakobsen science team lead



MIRI Fields of View

It is not possible to simultaneously observe the same field with imager and spectrometer



- MIRI has an imager, F ~ 100 spectrograph, and R=3000 IFU spectrometer (G. Wright PI; G. Rieke science lead)



Instrument Properties



Key Instrument Characteristics (as of Mar 06)									
Instrument	Channel/Mode	Wavelength (microns)	Typical Spectral Resolution ($\lambda/\Delta\lambda$)	FOV	Angular Resolution (arc sec)	Number of Sensor Chip Arrays	Mega Pixels	Detector Type / Format NIR=18 um pixels MIR=25 um pixels	Detector Temp (K)
NIRCam	Shortwave	0.6 - 2.3	4,10,100	2.2' x 2.2' each of 2 modules	0.032 / pixel	8	34	HgCdTe / 2048 x 2048	40
	Longwave	2.4 - 5.0	4,10,100	2.2' x 2.2' each of 2 modules	0.065 / pixel	2	8	HgCdTe / 2048 x 2048	40
NIRSpec	Multi-Object Spec	1.0 - 5.0	1000	203 x 463 mas clear shutter aperture, 267 x 528 mas pitch, 4 x 171 x 365 shutter array format, 9.7 sq arcmin multi-object targetable solid angle	see FOV	2	8	HgCdTe / 2048 x 2048	37
		0.6 - 5.0	100						
	Long Slits (5)	1.0 - 5.0	100, 1000, 2700	200 x 3500 mas x 3, 400 x 4000 mas, 100 x 2000 mas					
	IFU	0.7 - 5.0	2700	3 x 3 arc-sec	0.10 slice width				
MIRI	Imager	5 - 27	4-6	1.9' x 1.4'	0.11 / pixel	1	1	Si:As / 1024 x 1024	7
	Low Res Slit	5 - 11	100	5" x 0.6"	see FOV	1	1	Si:As / 1024 x 1024	7
	Med Res IFU	4.87 - 7.76	3000	3.7" x 3.7"	0.18 slice width	1	1	Si:As / 1024 x 1024	7
		7.45 - 11.87	3000	4.7" x 4.5"	0.28 slice width				
		11.47 - 18.24	3000	6.2" x 6.1"	0.39 slice width				
		17.54 - 28.82	2250	7.1" x 7.7"	0.65 slice width				
FGS-TF		1.6 - 2.5, 3.2 - 4.9	100	2.2' x 2.2'	0.065 / pixel	1	4	HgCdTe / 2048 x 2048	40
FGS-Guider		0.8 - 5.0	0.7	2.3' x 2.3' each of 2 modules	0.068 / pixel	2	8	HgCdTe / 2048 x 2048	40

Table courtesy of Matt Greenhouse, JWST ISIM Project Scientist



Estimated Sensitivities

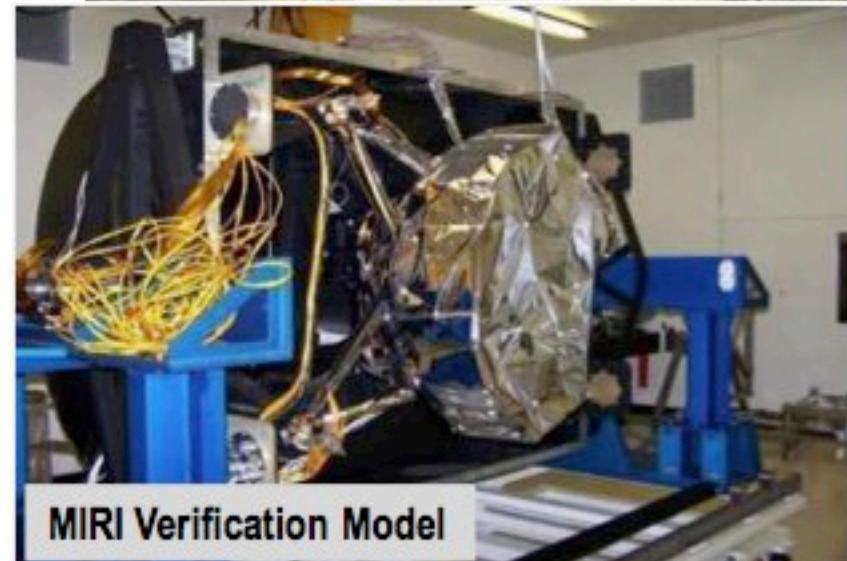
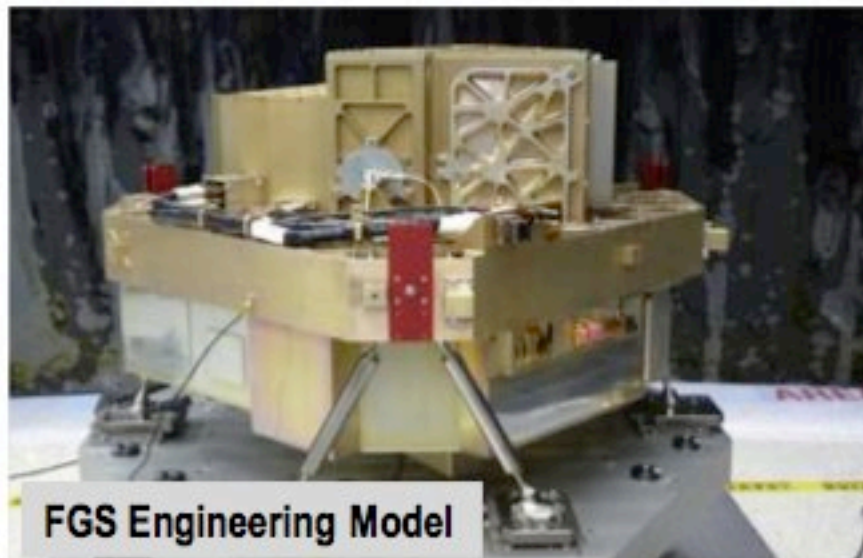
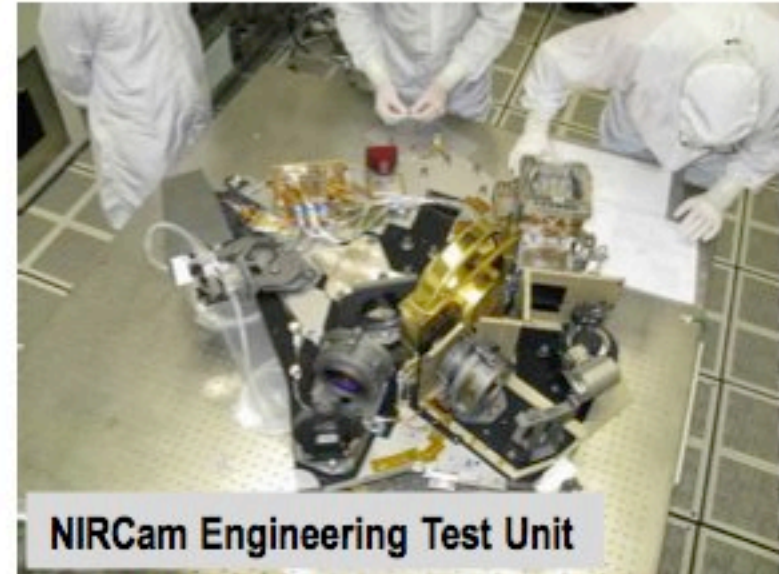
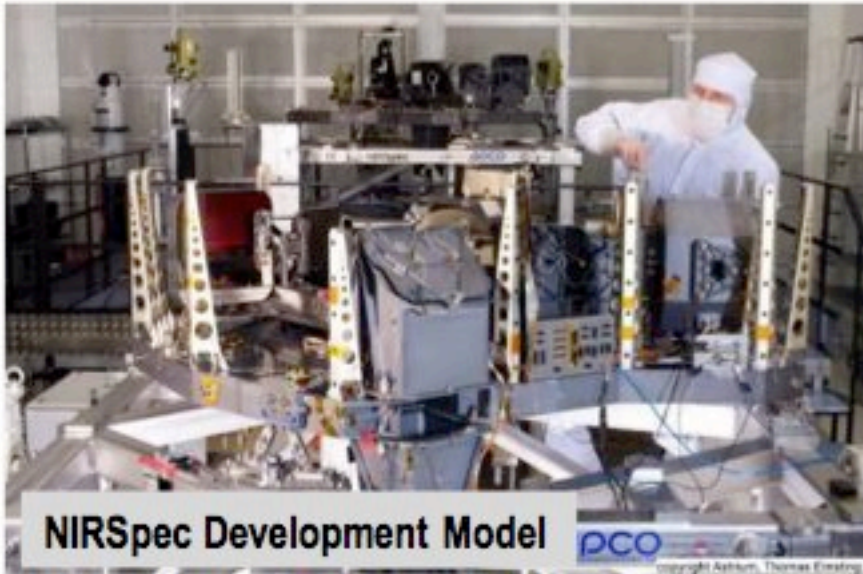


JWST Sensitivity (JWST-RQMT-000634 Rev-M proposed)							
Wavelength (microns)	Instrument/Mode	Bandwidth (l/Dl)	SNR	Maximum Wall Clock Time (s)	Continuum Flux Density (nJy)	Continuum Flux Density ($10^{-33} \text{ W m}^{-2} \text{ Hz}^{-1}$)	Unresolved Line Flux ($10^{-21} \text{ W m}^{-2}$)
1.1	NIRCam	4	10	10,000	TBD	TBD	NA
2	NIRCam	4	10	10,000	10.40	0.10	NA
3.5	FGS-TF	100	10	10,000	126.00	1.26	NA
3	NIRSpec/Low Res	100	10	10,000	120.00	1.20	NA
2	NIRSpec/ Med Res	NA	10	100,000	NA	NA	1
10	MIRI/ Broadband	5	10	10,000	700.00	7.00	NA
21	MIRI/Broadband	4.2	10	10,000	8700.00	87.00	NA
9.9	MIRI/Spectrometer	NA	10	10,000	NA	NA	10
22.5	MIRI/Spectrometer	NA	10	10,000	NA	NA	560

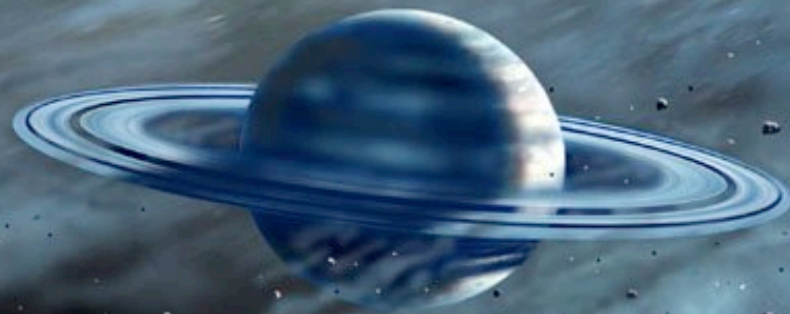
- MIRI R=3000 IFU is currently estimated to have point source sensitivity $F_{\nu} \sim 500 \text{ nJy}$ @ $S/N = 10$ in $1E4 \text{ s}$ in wide $10 \mu\text{m}$ filter
- Please take all values as estimates only: better values should be provided by June 2011

Status

- All instrument engineering models built, flight models to be delivered in 2011



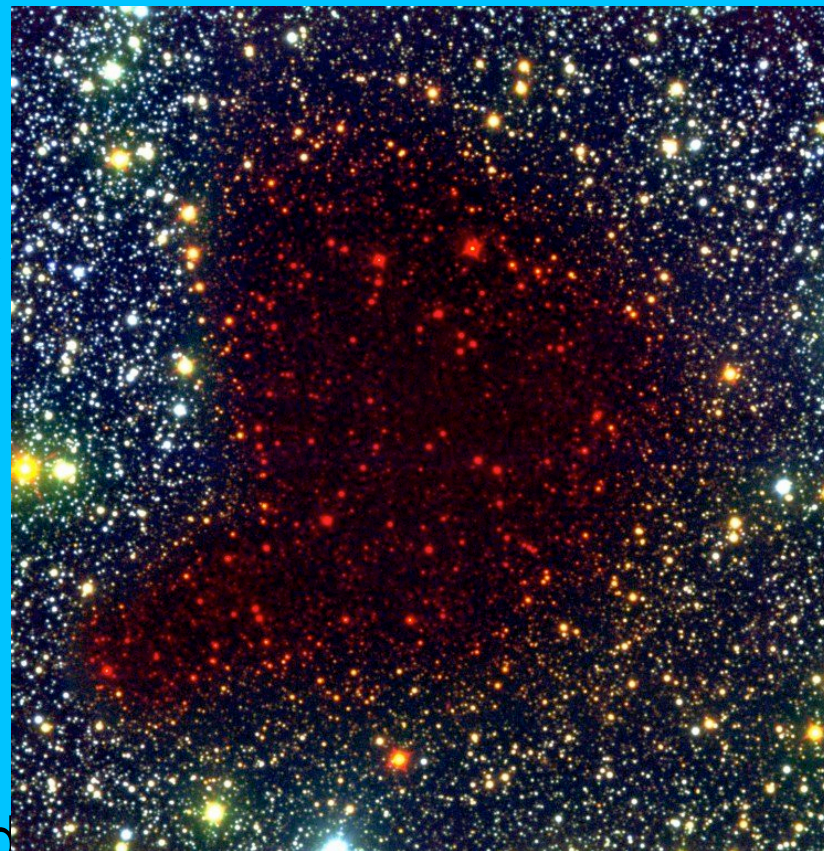
Birth of stars and protoplanetary systems



... to unravel the birth and early evolution of stars, from infall on to dust-enshrouded protostars, to the genesis of planetary systems.

How do proto-stellar clouds collapse?

- Stars form in small regions collapsing gravitationally within larger molecular clouds.
- We can see through thick, dusty clouds in the infrared.
- Protostars begin to shine within the clouds, revealing temperature and density structure.
- Observations consist of near- and mid-IR images that are used to create extinction maps via color and number information of background stars

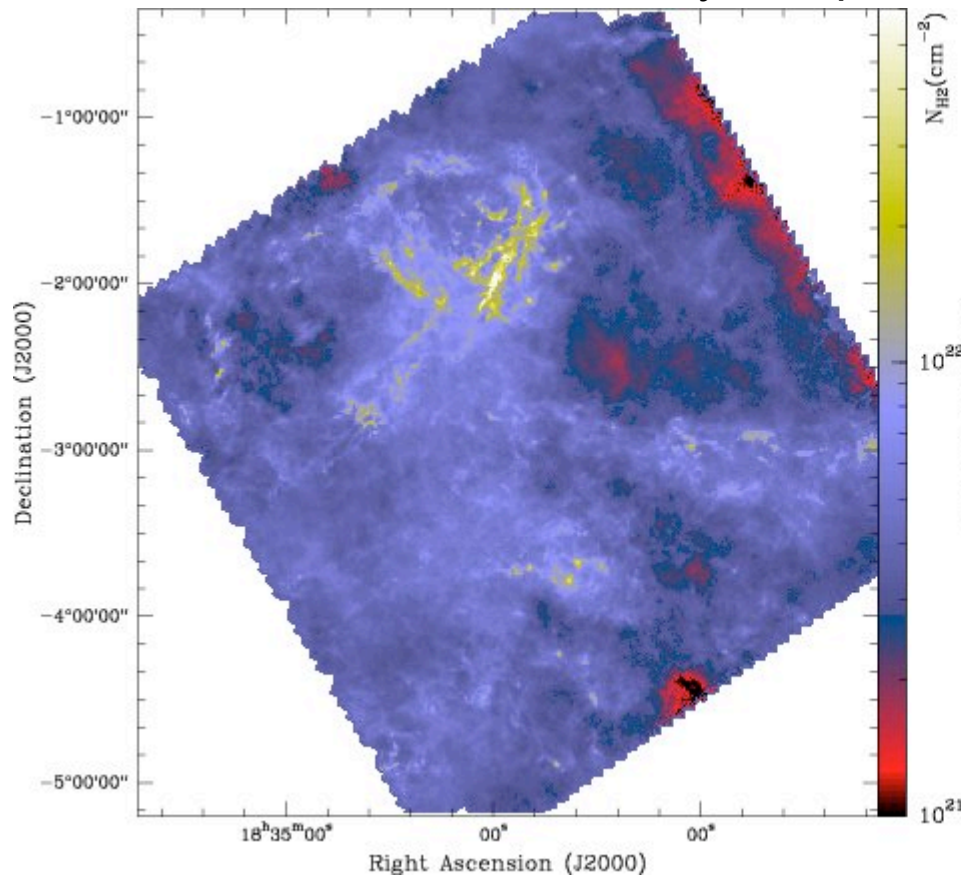


Barnard 68 in ~~visible~~ infrared light

Emission vs. Extinction maps

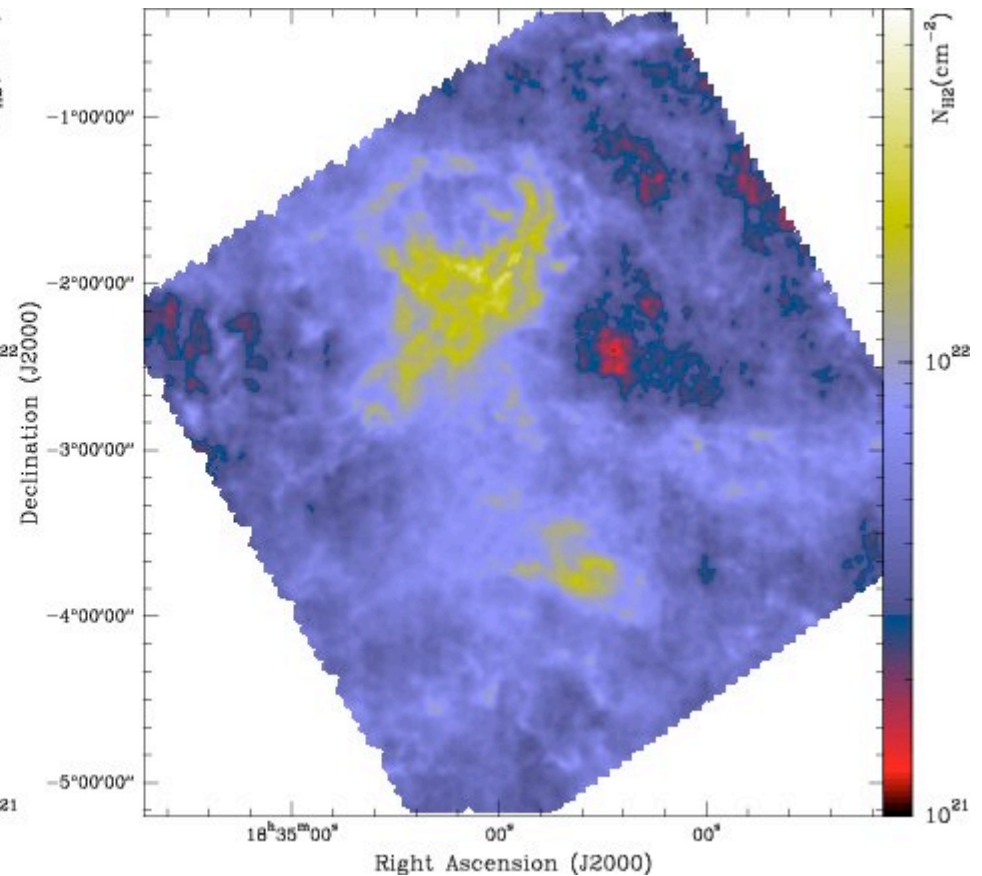
- High JWST sensitivity allows much deeper penetration and much finer sampling than ground-based extinction mapping:

Herschel Column Density of Aquila



Könyves et al. 2010

2MASS extinction map of Aquila



Könyves et al. 2010 / Bontemps et al. 2010

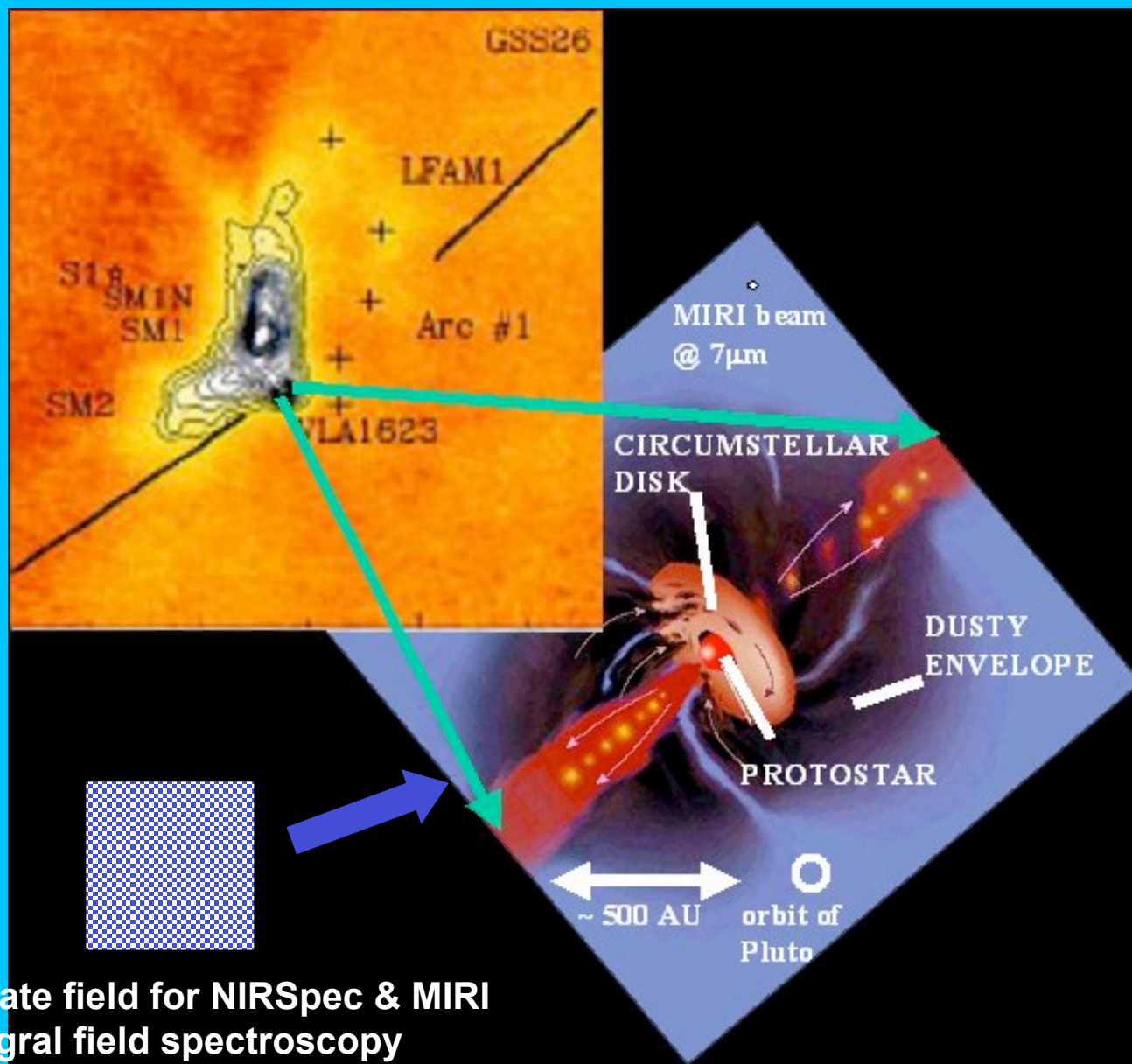
How do planets form?

- Giant planets could be signpost of process that creates Earth-like planets
- Solar System primordial disk is now in small planets, moons, asteroids and comets
- **Observations:**
 - Coronagraphic imaging of very young exosolar planets
 - Compare spectra of comets and circumstellar disks



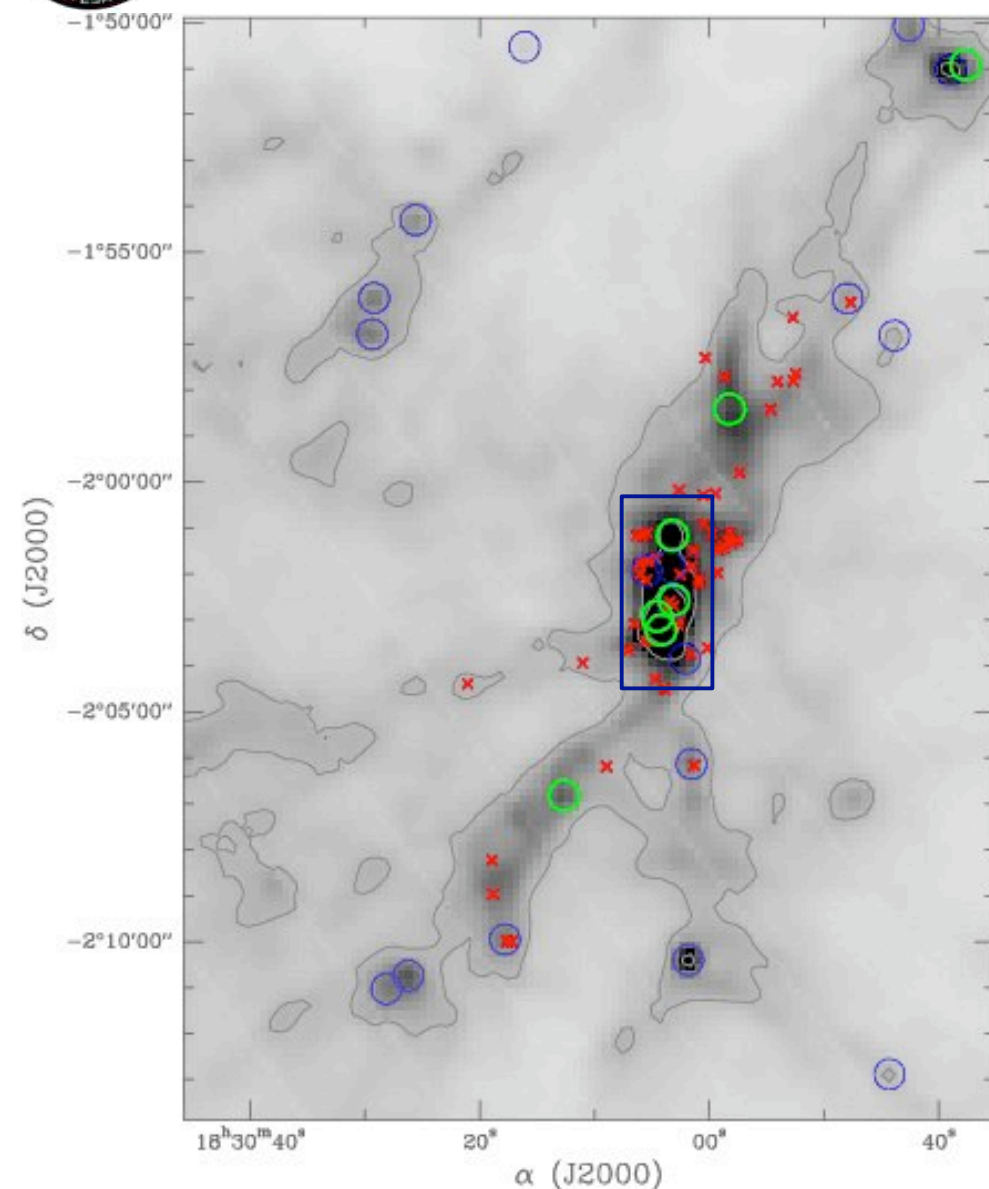
How are circumstellar disks like our Solar System?

Here is an illustration of what MIRI might find within the very young core in Ophiuchus, VLA 1623



approximate field for NIRSpect & MIRI
integral field spectroscopy

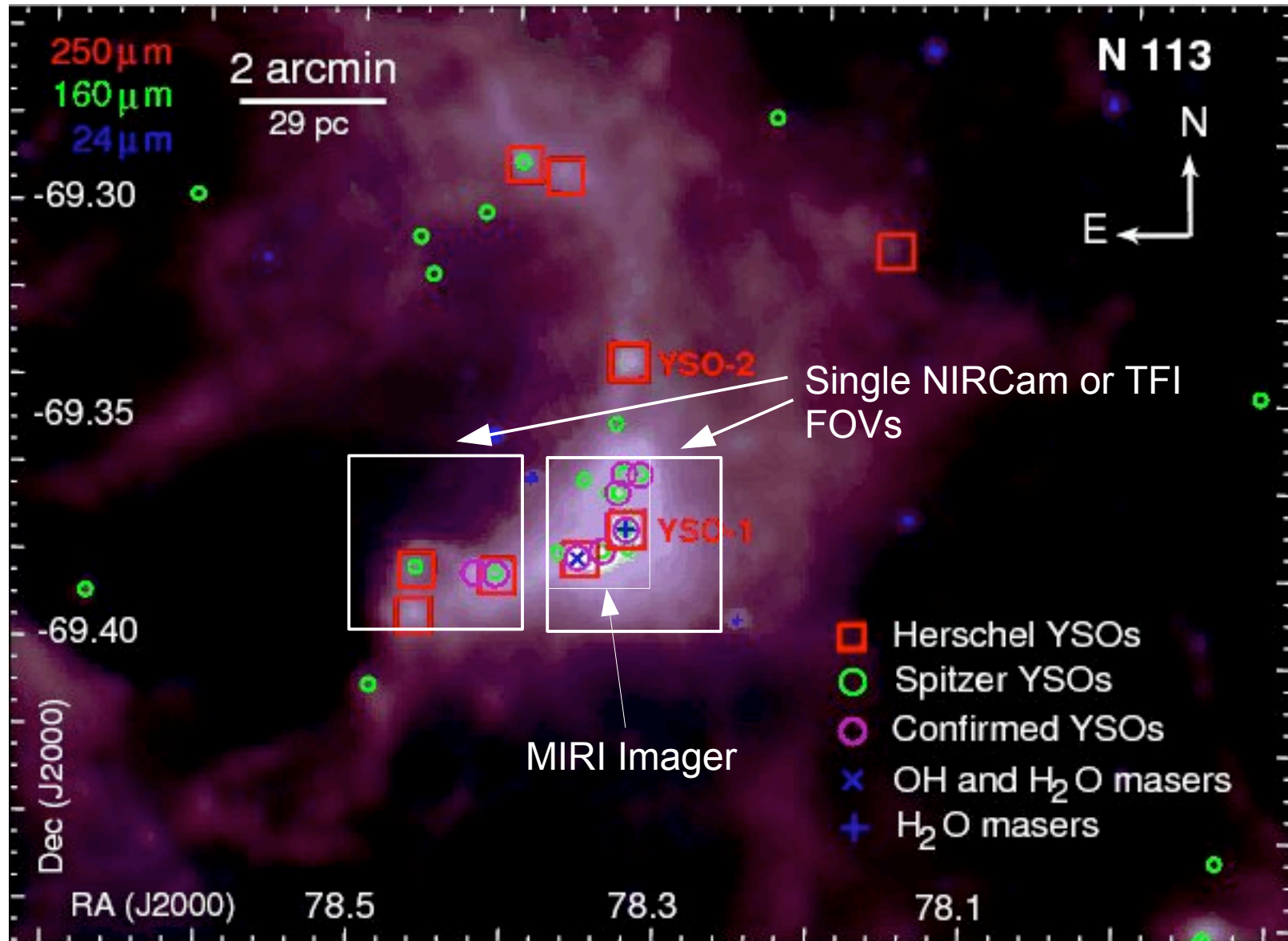
JWST and Herschel: nearby dark clouds



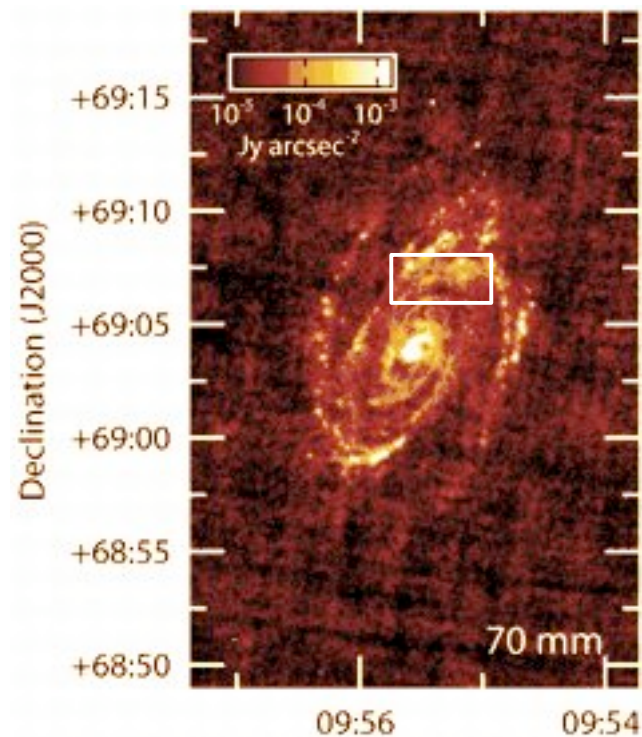
Serpens Herschel SPIRE 350 μm image & protostars (green) Bontemps et al. 2010

- Herschel PACS & SPIRE find the most embedded objects
- JWST will observe those protostars in detail:
 - Both NIRCам fields shown
 - TFI line imaging
 - NIRSspec MOS R=3000 spectra
 - MIRI images and IFU spectroscopy

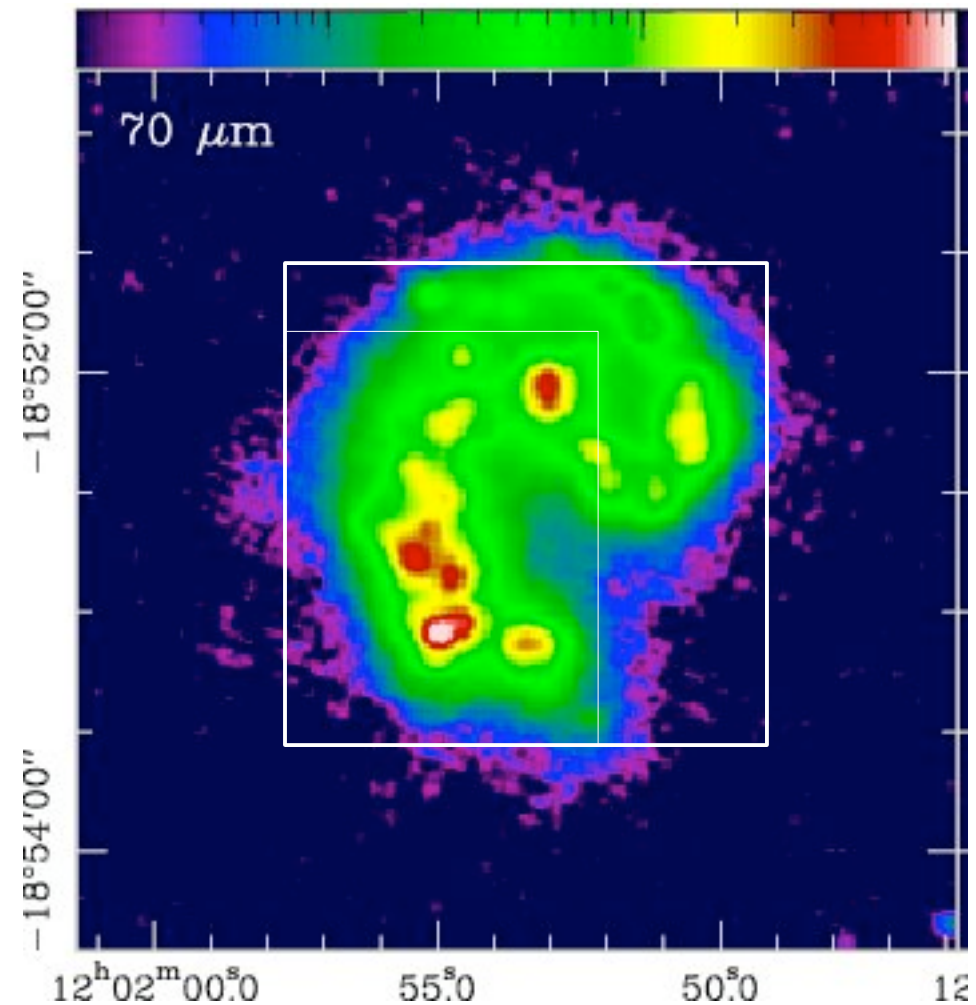
JWST and Herschel: LMC



Sewilo et al. (2010): SPIRE, PACS, and Spitzer MIPS. Herschel objects in red boxes



Bendo et al. (2010) PACS M81
 - Dual NIRCams fields shown
 - Can map star formation in a few pointings



Klaas et al. (2010) PACS Antennae
 - single NIRCams / TFI field shown
 - MIRI field inset



Other JWST Star Formation/ ISM thoughts



- Probe structure of protostellar envelopes with deep mid-IR imaging
- Chemistry of circumstellar envelopes with mid-IR spectra
- Probe “bottom end” of the initial mass function with multi-object spectroscopy of young clusters
- Images and spectra of jets in high and low mass star formation regions to study cessation of infall and entrainment of outflows
- Multi-epoch images to search for jet & stellar variability and investigate dynamical motions
- Tunable filter imaging of H₂, PAH, HI Br, and other line emission